DRAFT General Framework for Prospective Modeling, with One Proposed Hypothesis on Delayed Mortality

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The purpose of this document is show how the prospective model proposed by Rick Deriso in his July 9, 1997 memo "Some thoughts about S-R model equivalence" can be used to evaluate alternative hypotheses about delayed mortality. We derive formulas which can be used to represent one hypothesis about delayed mortality in prospective models, and provide rationale for the relevance of that hypothesis. We algebraically express system survival, and show how it can be used to evaluate this hypothesis. We also describe methods for linking passage model outputs to the prospective model. We describe how delayed mortality can be de-linked from direct passage mortality, allowing evaluation of hypotheses in which delayed mortality is not a consequence of passage experience.

Introduction

PATH is an iterative process of defining and testing a logical framework of hypotheses relating to the Columbia River anadromous salmonid ecosystem, while moving towards stock recovery and rebuilding (Marmorek and Peters 1996). A critical step is to lay out alternative hypotheses for the functioning of these ecosystem components, their response to management actions, and their ultimate impact on salmonid production. The logical framework developed in PATH is driven by the management questions of interest, the alternative hypotheses relevant to these questions, and the data available to test these hypotheses (ibid.).

At present, there are no fully articulated alternative hypotheses for testing in the PATH process, however, several alternative hypotheses have been discussed (e.g., Williams et al. 1997). The alpha model, as proposed (Anderson and Hinrichsen 1997b), combines the delta and delta m from the Deriso model, and reduces the Ricker "a" parameter (intrinsic productivity) accordingly.

Prospective Model Configuration 1

The first version of the Deriso model is

$$\ln(R_{y,i}) = (1+p)\ln(S_{y,i}) + a_i - b_i S_{y,i} - M_{y,i} - \Delta m_{y,i} + \delta_y + \varepsilon_{y,i} \qquad (1)$$

where symbols have the same definition as in equation (a) of Deriso's July 9, 1997 memo, except for substitutions and additions listed below. The delayed mortality term, Δm, can be formulated to match specific hypotheses about the causes of delayed mortality. In this example, it is formulated to represent the hypothesis that delayed mortality is conditioned by mainstem passage experience.

Terms and derivations:

Smolts can pass the hydrosystem by one of five routes (subscripts 1,2,3,5, n). The numbers represent dams where collection takes place, in order from the top of the reservoir: 1 = LGR, 2 = LGO, 3 = LMN, 5 = MCN. The subscript 'n' represents smolts which are never transported, i.e., smolts which migrate in-river through the entire hydrosystem.

y = year (shown in equations 1, 14, 15, and 16 only)
i = region
j = passage route
t = transported
n = non-transported
b = at Bonneville tailrace

Note: All variables described afterward in this section refer to annual seasonal values: the 'y' subscript is omitted for simplicity.

N_0 = total number of smolts at top of first reservoir in a season
N_j = number of smolts reaching the forebay of dam j
L_j = cumulative in-river survival from top of first reservoir to dam j
$N_{j,t}$ = number of smolts collected for transportation from dam j
$N_{0,t} = \Sigma_j [N_{j,t}/L_j]$ = total number of smolts destined for transportation during a season
$N_{0,n} = N_0 - N_{0,t}$ = total number of smolts not destined for transportation during a season
$N_{b,j}$ = Number of smolts alive at Bonneville that were transported from dam j
$N_{b,t}$ = total number of smolts alive at Bonneville that were transported during a season
$N_{b,n}$ = total number of smolts alive at Bonneville that were not transported during a season
N_b = total number of smolts alive at Bonneville during a season
$M = -\ln(N_b/N_0)$, direct passage river mortality over a season
$P_{b,j}$ = proportion of smolts at Bonneville which were transported from dam j
$P_{b,n}$ = proportion of smolts at Bonneville which were not transported
$P_{b,t} = N_{b,t}/N_b$ = proportion of smolts at Bonneville which were transported during a season
$V_n = N_{b,n} / N_{0,n}$ = direct passage survival of smolts passing in-river
$V_j = L_j$ * bypasssurv * bargesurv = direct passage survival of smolts transported at dam j
$P_j = N_{j,t} / N_j$ = proportion of smolts arriving in-river at dam j that are bypassed for collection at dam j
$P_{0,j}$ = proportion of smolts at head of first reservoir destined to pass by route j

Estimates of values for P's, L, and V's come from a passage model.

Derivation of $P_{0,j}$'s:

$P_{0,j} = P_j$ if j = 1

$$P_{0,j} = P_j \cdot \prod_{k=1}^{j-1}(1-P_k) \quad \text{if } j > 1, \neq n$$

If j = n, then $P_{0,j}$ = proportion of smolts destined to pass in-river = $P_{0,n}$
and

$$P_{0,n} = 1 - \sum_{j=1}^{5} P_{0,j} \qquad (2)$$

The delayed mortality component, given a particular passage model, can be estimated by setting it equal to the MLE estimate of direct and delayed passage mortality (m in Chapter 5) minus an estimate of direct passage mortality (M, above). Then,

$$\Delta m = m - M, \text{ with } m = M_d + \mu. \qquad (3)$$

where M_d is the direct passage mortality for downriver stocks and μ is net (direct + delayed) instantaneous mortality from the Snake River subbasins to the John Day dam. Annual estimates of M and M_d would be provided by survival estimates from the passage models without any delayed mortality applied. For downriver stocks, μ by definition is equal to zero; therefore for downriver stocks $m = M$ (= M_d), so $\Delta m = 0$.

Delayed mortality as a function of direct passage mortality and transport fraction

Later in this paper we present a hypothesis and rationale relating to delayed mortality of upstream stocks, relative to downstream stocks, as a consequence of downstream passage experience. Here we present algebraic description of the testing and modeling of this hypothesis; some of the derivation is relevant to alternative hypotheses that also distinguish between delayed mortality of transported and non-transported fish.

For prospective model runs, it may be possible to derive a relationship between Δm and M and allocate delayed effects between transported and non-transported smolts. This would be done by relating $m - M$, where M is historical estimate of direct mortality from the passage models and m's are yearly estimates of total passage mortality from retrospective model run, to an index of M (say M') that incorporates the relative delayed mortality of transported and in-river migrants. This is done by weighting each group's contribution to M by the delayed survival that group of smolts would be expected to experience divided by the overall or average delayed survival of the entire migration. This procedure is described below.

Many hypotheses about Δm can be evaluated. For example, information from transport/control studies and estimates of in-river survival to each point of collection, below each point of collection, and for the whole reach could be used. Under the hypothesis of delayed mortality affected by direct passage survival and transport/in-river experience, delayed mortality of smolts passing through each route could be predicted from this relationship:

$$\Delta m = -\ln\left(P_{b,n}\lambda_n + \sum_{j=1}^{5} P_{b,j}\lambda_j \right) \tag{4}$$

where

λ_j = "delayed survival (post-Bonnneville) factor" for smolts transported from j; must be ≥ 0
λ_n = "delayed survival factor" for smolts not transported; must be ≥ 0

The ratio of "delayed survival" for transported smolts to that of non-transported smolts can be derived from the transport studies and projections of in-river survival from the passage models. Under the assumption that the delayed survival of smolts transported from different projects in the same year varies inversely with cumulative direct survival, the transport/in-river ratio can be related to λ_j and λ_n. To isolate the ratio of delayed survivals from overall ratio of transport to in-river survival, the overall ratio must be adjusted by the ratio of direct survivals:

$$\frac{\lambda_j}{\lambda_n} = \Phi \frac{V_n}{V_j} \tag{5}$$

where Φ = transport/in-river ratio for year, e.g. a function of V_n or WTT, from a transport model based on data from T/C (transport/control) studies.

<u>Calculation of λ_j 's and λ_n:</u>

From Chapter 5, *m* is direct passage and delayed mortality. We can set annual estimates of *m* from the retrospective analysis equal to the negative natural log of direct passage and delayed smolt to adult recruit survival in terms of the current model (or alternatively, set exp(-*m*) equal to the direct survival and delayed SAR):

$$\exp(-m) = V_n P_{0,n}\lambda_n + \sum_{j=1}^{5} V_j P_{0,j}\lambda_j \ .$$

Substituting for λ_j:

$$\exp(-m) = V_n P_{0,n}\lambda_n + \sum_{j=1}^{5}\left(V_j P_{0,j} \cdot \frac{\Phi V_n \lambda_n}{V_j} \right)$$

$$= V_n \lambda_n \left(P_{0,n} + \Phi \sum_{j=1}^{5} \frac{V_j P_{0,j}}{V_j} \right)$$

$$= V_n \lambda_n \left(P_{0,n} + \Phi \sum_{j=1}^{5} P_{0,j} \right).$$

So (from equation 2):

$$\exp(-m) = V_n \lambda_n \left[P_{0,n} + \Phi(1 - P_{0,n}) \right]. \tag{6}$$

With m estimates provided from the retrospective MLE analysis, V_n and $P_{0,n}$ estimates from passage models, and Φ from transport studies and passage models, λ_j's and λ_n can be estimated from equations 6 and 5.

The Δm values can be plotted against an index which combines direct hydrosystem passage mortality and transport portion, to develop a function for predicting future Δm. A Δm would be predicted by using the derived function with the future value of this index (M'). Simply using direct passage survival (M) as the index for predicting Δm doesn't allow differential delayed survival of transported and non-transported fish to affect Δm. This is because a given value of M could be produced by many different passage scenarios involving very different proportions of transported vs. non-transported fish. Instead, the index (M') should involve weighting of the component from each passage route according to the delayed survival experienced by fish passing that route, relative to the overall delayed survival. M' would be described by:

$$M' = -\ln\left(V_n P_{0,n} w_n + \sum_{j=1}^{5} V_j P_{0,j} w_j \right) \tag{7}$$

where w_n is the weight applied to in-river fish and w_j is the weight applied to smolts transported from dam j. The weights can be derived by dividing the proportion of adult recruits from a particular passage route by the proportion of smolts at Bonneville from that same route. For non-transported fish:

$$w_n = \frac{R_n / R}{N_{b,n} / N_b}$$

and

$$\frac{R_n}{R} = \frac{N_{b,n} \lambda_n \exp(\delta)}{\left(N_{b,n} \lambda_n + \sum_{j=1}^{5} N_{b,j} \lambda_j \right) \exp(\delta)}, \qquad \frac{N_{b,n}}{N_b} = \frac{N_{b,n}}{N_{b,n} + \sum_{j=1}^{5} N_{b,j}}$$

After substituting in terms of N_0, direct survivals (V_j's and V_n) and proportions ($P_{0,j}$'s) and for λ_j using equation 4, and simplifying, we have

$$w_n = \frac{P_{0,n} + \dfrac{\sum_{j=1}^{5} P_{0,j} V_j}{V_n}}{P_{0,n} + \Phi(1 - P_{0,n})} \tag{8}$$

This weight can also be expressed in terms of the proportion of smolts arriving at BON through different routes:

$$w_n = \frac{\lambda_n}{\Delta m} = \frac{\lambda_n}{P_{b,n}\lambda_n + \sum_{j=1}^{5} P_{b,j}\lambda_j} = \frac{\lambda_n}{P_{b,n}\lambda_n + \sum_{j=1}^{5} P_{b,j}\lambda_n \Phi \dfrac{V_n}{V_j}} = \frac{1}{P_{b,n} + \Phi V_n \sum_{j=1}^{5} \dfrac{P_{b,j}}{V_j}} \tag{9}$$

The weight to apply to smolts transported from dam j can be derived similarly:

$$w_j = \frac{R_j / R}{N_{b,j} / N_b}$$

$$\frac{R_j}{R} = \frac{N_{b,j}\lambda_j \exp(\delta)}{\left(N_{b,n}\lambda_n + \sum_{j=1}^{5} N_{b,j}\lambda_j\right)\exp(\delta)}, \quad \frac{N_{b,j}}{N_b} = \frac{N_{b,j}}{N_{b,n} + \sum_{j=1}^{5} N_{b,j}}.$$

Then, after substituting and simplifying,

$$w_j = \frac{\dfrac{\Phi}{V_j}\left(P_{0,n}V_{0,n} + \sum_{j=1}^{5} P_{0,j} V_j\right)}{P_{0,n} + \Phi(1 - P_{0,n})} \tag{10}$$

These weights can also be expressed in terms of the proportion of smolts arriving at BON through different routes:

$$w_j = \frac{\lambda_j}{\Delta m} = \frac{\lambda_j}{P_{b,n}\lambda_n + \sum_{j=1}^{5} P_{b,j}\lambda_j} = \frac{\lambda_n \Phi\left(V_n / V_j\right)}{P_{b,n}\lambda_n + \sum_{j=1}^{5} P_{b,j}\lambda_n \Phi \dfrac{V_n}{V_j}} = \frac{\Phi\left(V_n / V_j\right)}{P_{b,n} + \Phi V_n \sum_{j=1}^{5} \dfrac{P_{b,j}}{V_j}} \tag{11}$$

In this form of the prospective model, i.e. with Δm separated from M, different hypotheses concerning possible causes of delayed mortality can be evaluated. These Δm's would be defined as reductions in spawner to recruit survival which is attributable to the post-Bonneville period. The Δm's represent an additional mortality applied to the upstream stocks, after the common year effect δ is applied to all stocks.

Prospective Model Configuration 2

Another approach that may be useful for segregating survival in the prospective model uses system survival (ω), which is the form that survival rates have been generated by the passage models in the past. This approach fits with in the general framework of the model described by equation (a) of Deriso memo of July 9, 1997 with different meanings of M and Δm. It is most consistent with the methods used in the past for linking passage and life-cycle models.

System survival is the number of in-river equivalent smolts below BON divided by the population at the head of the first reservoir. The numbers of transported smolts at each collector project that survive to BON are converted into in-river equivalents by adjusting for differential delayed mortality using the transport/control ratio (Φ) and in-river survival (V_n). System survival is then

$$\omega = P_{0,n}V_n + \Phi V_n(1-P_{0,n}) = V_n\left[P_{0,n} + \Phi\left(1-P_{0,n}\right)\right] \tag{12}$$

The ratio of exp($-m$) (equation 6) and ω is the post-Bonneville survival of in-river equivalent fish. That is:

$$\omega = \frac{\exp\left(-m\right)}{\lambda_n} \tag{13}$$

In this case the delayed mortality associated with in-river fish, given a particular passage model, can be estimated by setting it equal to the MLE estimate of direct and delayed passage mortality (m in Chapter 5) minus an estimate of $-\ln(\omega)$ (the instantaneous system mortality). This difference is $-\ln(\lambda_n)$, which is the delayed instantaneous mortality of in-river equivalent fish. The model can be expressed as:

$$\ln(R_{y,i}) = (1+p)\ln(S_{y,i}) + a_i - b_i S_{y,i} + \ln(\omega_{y,i}) + \ln(\lambda_{n,y,i}) + \delta_y + \varepsilon_{y,i} \tag{14}$$

In this version of the prospective model, one method of deriving future delayed mortality of the form $-\ln(\lambda_n)$ is to plot the retrospective values of $-\ln(\lambda_n)$ against $-\ln(\omega)$ retrospective values to develop a function relating them. Then, a future $-\ln(\lambda_n)$ can be derived from a -ln(ω) generated from a passage model run analyzing proposed management actions.

Alternatively, the assumption that delayed mortality is directly proportional to system survival can be evaluated. The first step to produce the future delayed mortality [-ln(λ_n)] is to select a retrospective *m* and ω and calculate λ_n from equation 13. In prospective model runs, the ratio of prospective to retrospective ω is used to adjust retrospective ω and λ_n in equation 14, in a manner similar to that described below in equation 16.

Alternative hypotheses about delayed mortality [-ln(λ_n)] can be expressed in this configuration of the model, as well.

Alternative Prospective Model Linkages

This proposed method of the prospective modeling is a linkage method used in previous life-cycle modeling approaches in the Biological Opinion assessments and ANCOOR model comparisons. In the past the linkage between the passage models and the life-cycle model consisted of passing a vector of ratios of annual future system survival (proposed management action) to a base system survival. The reason for this linkage approach is that we are interested in the relative improvement in survival from some set of actions as predicted through the passage models and not the absolute predictive capability of the passage models for those set of actions. The ratios were used to adjust predicted recruits in the life-cycle model. This type of linkage can be employed in a prospective model as follows:

$$\ln(R_{y,i}) = (1+p)\ln(S_{y,i}) + a_i - b_i S_{y,i} - m_{y,i} + \ln\left[\omega_p / \omega_r\right] + \delta_{y,i} + \varepsilon_{y,i} \qquad (15)$$

where,

ω_r = retrospective or base system survival (without future management action)

ω_p = prospective or future system survival (with future management action)

This approach to passage model linkage can also be applied to the more general form of the prospective model as:

$$\ln(R_{y,i}) = (1+p)\ln(S_{y,i}) + a_i - b_i S_{y,i} - M_{y,i} + \ln\left[\omega_p / \omega_r\right] - \Delta m_{y,i} + \ln\left[\omega_p / \omega_r\right] + \delta_y + \varepsilon_{y,i}$$

(16)

The improvement in delayed survival is directly proportional to improvement in system survival.

Rationale for Proposed Hypothesis for Prospective Modeling

Hypothesis:

The completion of the Federal Columbia River Power System in the late 1960s through the mid-1970s, by increasing the direct and delayed mortality of juvenile migrants, resulted in considerably sharper declines in survival rates of Snake River stocks (over the same time period), than of stocks which migrate past fewer dams and are not transported.

Rationale:

Several plausible mechanisms were identified from the literature in Weber et al. (1997) that may explain delayed mortality of smolts that are transported and those that migrate in-river through the hydropower system. These include: altered saltwater entry timing which is poorly synchronized with the physiological state of the smolts; stress from crowding and injury (including descaling) during bypass, collection, holding and transport; increased vulnerability to disease outbreak (e.g., BKD and fungal infection) due to stress and injury; and increased vulnerability to other stressors in the environment or to predation, particularly by northern squawfish.

Evidence for delayed mortality due to hydrosystem passage comes in part from the PATH 1996 conclusions on the retrospective analysis (Marmorek and Peters 1996), stock-recruitment comparisons (Schaller et al. 1996) and the MLE retrospective model (Deriso et al. 1996). MLE estimates of mu, which include direct and delayed passage mortality components, were correlated with water travel times experienced during the smolt outmigration; total mortality of Snake River spring/summer chinook tended to be highest in low flow, low spill years which had higher proportions of smolts transported. Passage models which assumed no delayed mortality of transported smolts (CRiSP T2) had the poorest fit in the MLE (e.g., Fig 5-5 of Deriso et al. 1996). In addition, estimated smolt-to-adult return (SAR) rates of transported Snake River smolts have been considerably less than the SARs prior to FCRPS completion, and less than the recent SARs of a similar downriver stock, Warm Springs River (Raymond 1988; Weber 1996; Weber et al. 1997).

Evidence for delayed mortality of transported smolts relative to those that pass in-river through the hydrosystem also comes from a comparison of in-river survival estimates and the inverse of the T/C ratio. If post-hydrosystem mortality were roughly equal between the transported and in-river groups as hypothesized by Williams et al. (1997), the points should scatter around the 1:1 line. However, the scatter of points from the 1968-1979 transportation and in-river survival studies tended to fall to the right and below the 1:1 line, which supported a hypothesis that delayed mortality was greater for transported fish than for the controls (Figure 1).

Preliminary analysis of return rates of PIT tagged wild smolts from 1993 to 1995 further suggests that delayed mortality of in-river migrants may be related to route of passage through the hydropower system. Smolts that were detected (i.e., were bypassed) two or more times returned at lower rates than those detected once (R. Kiefer, IDFG, personal communication). Also, those wild smolts that were never detected in 1995 (i.e., those estimated to be alive at LGR tailrace and passed through collector projects via a combination of spill and turbine routes) returned at a higher rate than those that were detected. Based on PATH estimates of direct mortality through bypass, spill and turbine routes, these results suggest that delayed mortality increases as a function of the number of times a fish is bypassed.

Use of a common year effect parameter reflects evidence that the estuary and early ocean conditions do not have a systematically different effect on survival for stream-type chinook stocks across regions of the interior Columbia River basin. This is reasonable in view of similarity of these stocks, the overlap in time and space of these stocks during their early ocean residence (and beyond), and the broad-scale nature of climatic influences described in the literature.

There are several lines of evidence suggesting that the interior Columbia Basin stocks are exposed to similar estuary and ocean conditions, particularly during the critical first year. Beamish and Bouillon (1993) and others provided evidence that indices of climate over the north Pacific Ocean may play an important role in production of different species of salmon originating over a wide geographic range. In a review paper, Anderson (1996b) concluded that a warm/dry regime favors stronger year class strengths of many Alaska fish stocks while cool/wet regime favors stocks on the West Coast of the lower United States. Deriso et al. (1996) found evidence of a common year effect for all index stocks of stream-type chinook from the Snake River and lower Columbia River regions. Of the lower Columbia River stocks in this analysis, at least the John Day River and Warm Springs River spring chinook smolt timing appears very similar to that of Snake River spring and summer chinook. Smolts of these lower Columbia River, Snake River and upper Columbia River stocks migrate through the mainstem to the estuary primarily in late April and May (Lindsay et al. 1986, 1989; Raymond 1979; Hymer et al. 1992; Mains and Smith 1964). Current hypotheses regarding ocean survival of Pacific salmon generally focus on the juveniles' critical first months at sea (Pearcy 1988, 1992; Lichatowich 1993), where juveniles of these index stocks are most likely to overlap in time and space. Year class strength for these spring and summer chinook is apparently established, for the most part, within the first year in the ocean, as evidenced by the ability of fishery managers to predict subsequent adult escapements from jack counts (e.g., Fryer and Schwartzberg 1993).

Although ocean recoveries of coded wire tagged spring/summer chinook are infrequent (Berkson 1991), the few recaptures (62 recoveries from 8 release years) from both Snake River (21 recoveries) and lower Columbia River (41 recoveries) hatchery stocks were widely scattered from California to Alaska ocean fisheries (PSMFC unpublished data). The average annual proportion of CWT recoveries from ocean fisheries north and south of the Columbia River mouth appears to be similar between the Snake and lower Columbia hatcheries (Figure 2). Since it appears that Columbia Basin stream-type chinook share a common estuary and nearshore ocean environment and a more common ocean distribution than stocks evaluated by Beamish and Bouillon (1993), it seems very unlikely that differential estuary and ocean conditions themselves (i.e., apart from differences in delayed effects due to juvenile migration) would have had a systematically different effect on survival.

Incorporation of Alternative Hypotheses

It is not clear which of the several proposed alternative hypotheses about delayed mortality unrelated to the hydropower system is to be tested in the present analysis. Without a specific hypothesis and rationale, we cannot provide an exact representation of how it would be formulated within either the alpha or Deriso framework. However, since the Δm's represent an additional mortality applied to the upstream stocks, after the common year effect δ is applied to all stocks, the Deriso model can be configured to represent hypotheses about the relation of Δm to a number of time-varying factors unrelated to direct hydrosystem mortality. These may be either partially related to or independent of the hydrosystem: e.g., 1) estuary and ocean conditions associated with the timing of arrival of smolts at the estuary; 2) land use and habitat quality indices; or 3) differential ocean survival or climate impacts unrelated to the hydrosystem.

For example, one hypothesis might be that delayed mortality is conditioned by arrival timing of smolts in the estuary relative to the spring transition period, as was proposed by Anderson (1996a). As Anderson (1996a) notes about the Deriso model:

> Under the estuary hypothesis the contention that upstream and downstream stocks have the same or different ocean distributions and ocean survivals is moot. They experience the same mortalities to the exten[t] described by the year effect δ. Any difference in mortalities in the estuary and ocean is contained in μ and the equation for the relationship is presented in the paper.

For the same reason, under a hypothesis of different estuary and/or ocean survival due to factors other than direct hydrosystem mortality and transport fraction, the differences in delayed mortality between stocks from different regions is contained in Δm. Any hypothesis that can be represented in the alpha model can be represented in the Deriso model. Hypotheses about non-hydrosystem, or multiple causes of this differential mortality can be modeled by expressing stock- or region-specific Δm as a function of whatever covariates are desired. The expression of m as direct + delayed ($M + \Delta m$) mortality in this paper and the resultant flexibility in representing various hypotheses satisfies all the concerns expressed in Anderson and Hinrichsen (1997a) about the "narrow interpretation of μ_t" that motivated development of the alpha model:

> The alpha alternatives allow for region-specific climatic effects while the mu alternatives do not.
>
> Climate factors are assumed to have no influence on μ_t. The model also assumes that any climate effects can be represented as a single Columbia Basin-wide variable δ_t and that passage mortality before 1970 is a step function which is proportional to the number of dams the stocks must pass. By including our alternatives we can determine how critical these assumptions are in the final prospective results.

Mu combines hydrosystem effects and differential ocean survival factors in a complex mixture that can not be clearly articulated for identifying the impacts of hydrosystem and climate factors for prospective analyses. Nor does it allow a clear articulation of the contributions of hydrosystem and climate factors on possible delayed mortality in transportation.

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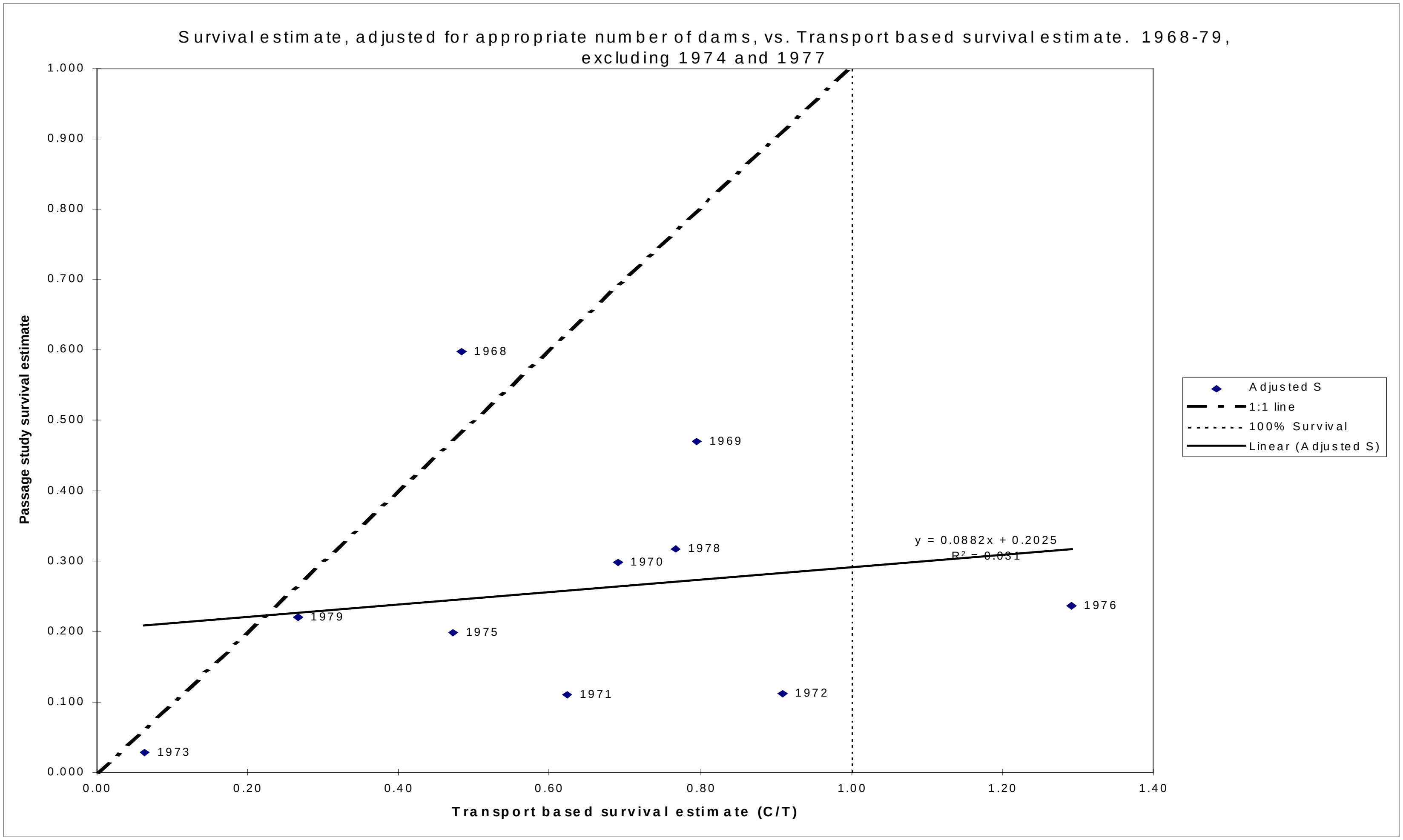

Figure 1. Yearly downstream passage study survival estimate vs. C/T. No transport study performed on 1974 migration; no controls returned from 1977 migration to estimate T/C. Adapted from Weber et al. (1997).

Figure 2. Observed Coded Wire Tag (CWT) Ocean Recoveries of Snake River and Lower Columbia River Hatchery Spring Chinook for release years 1983-90. Source: Weber et al. (1997)